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An Online Expert System for Diagnostic Assessment Procedures on Young Children's Oral Speech and Language

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Abstract

Internet has influenced many aspects of modern life, as it gave people the opportunity to access massive amount of information. Information & Communication Technologies (ICT) offer the option to analyze, organize, synthesize and transmit information and therefore contribute and reveal valuable clinical and educational tools.

The aim of the present study is to report on the development of an Internet based Speech Pathology Expert System in Greek, named APLo, intended to be used by clinicians and teachers involved in oral language learning and strengthening of four to seven year old children. This system embeds the expert's knowledge on oral language assessment. A hybrid approach that integrates symbolic rules with neural networks is being used to model and represent the knowledge in the system. Particular attention is given to the validation and verification of the system. Potentials, further use and developments for upgrading e-evaluation/e-assessment of speech and language disorders and protocols according to technological and scientific advances are discussed.

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Keywords: online diagnosis; web-based diagnosis; expert system; children's speech and language disorders; speech and language assessment; Greek language

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1. Introduction

1.1. Speech and language disorders

People may experience speech and language difficulties at any stage of their life. Adults may deal with [1] (i) speech disorders such as apraxia, dysarthria, stuttering and voice, (ii) language disorders such as aphasia, (iii) communication disabilities (AAC – augmentative and alternative communication, speech for people with tracheostomies or ventilators) and (iv) elective issues (accent modification, voice and communication therapy for transgender/transsexual). Children may deal with [2]: (i) speech disorders (childhood apraxia of speech, dysarthria, orofacial myofunctional disorders, speech sound disorders (articulation and phonological processes, stuttering, voice), (ii) language disorders (language-based learning disabilities, preschool language disorders, selective mutism), (iii) medical and developmental conditions (attention deficit/hyperactivity disorder, autism, cleft lip and palate, right hemisphere brain injury, traumatic brain injury) and (iv) communication disabilities (AAC, speech for people with tracheostomies or ventilators). Amongst the causes of speech and language disorders are hearing loss, autism, mental retardation, neurological disorders, stroke, brain injury, physical impairments such as cleft lip or palate, and so on.

Most speech disorders are met during childhood and several of them are solved with a short intervention [3]. The detection and quantification of speech and language disorders and difficulties require specialized knowledge and skills [4]. Focusing on the children's assessment, the identification of deficits that impact upon the expression and/or reception of speech and language is important. The role of teachers and parents is fundamental in referring a child for speech and language assessment and is well established in the diagnosis and intervention stages [5]. Teachers and parents, in everyday activities, observe children's language development and usually they are the ones who may notice a shortage for example in articulation or early warning signs on learning issues such as language development, phonological awareness, perceptual-motor abilities, attention [6] and so on. Therefore, a diagnosis should take place in order for a special intervention to be planned to gain age-appropriate speech and language skills. The early identification of speech and language disorders and/or delays is a crucial first step in the effective prevention of developmental and socioemotional problems [7, 8]. Children's early cognitive and language development is fundamental on later development and readiness for learning and social competence [7].

Assessment and diagnosis of speech and language disorders and difficulties are very important in both educational and medical practice. Although speech and language disorders do not threaten a person's life, they can cause various communication problems and seriously affect interpersonal relations [9].

1.2. Information & Communication Technologies, assessment and diagnosis

The continuous advances on Information & Communication Technologies (ICT) are an essential part of modern life affecting human communications and enabling support for all forms of communication between people. Forms of communication may vary from simple messaging (email) to supporting professionals on decision making. Likewise, ICT have been accommodating, apart from administrative tasks, various more vital tasks in speech and language pathology [3] (i) the use in therapeutic phases in many ways, by the simple replacement of drawing instructive and educational materials with images, sounds, texts in a multimedia environment, to the use of speech technology presenting and allowing visualization of different dimension of speech and (ii) the use in diagnostic phases, by creating rich and appropriate environments of instructive materials, to the use of the computer as a real assistant for the speech and language evaluation and diagnosis. ICT can contribute to expand and develop valuable clinical and educational tools for speech and language disorders.

The literature refers to the positive impact of ICT usage in children with normally or delayed speech and language skills [9, 10]. More specifically, research on the ICT usage in terms of tele-education and tele-health for assessment, diagnosis, support and rehabilitation of communication disorders have revealed positive results in neurogenic communication disorders, disorders in dysphagia, childhood speech and language disorders, learning and cognitive disabilities [11-17].

Advanced computerized systems to assist the detection/diagnosis and treatment/rehabilitation of Speech-Language Pathology in Greek are discussed in the literature [3, 12-14, 16-23]. Nevertheless, there is no reference of a computer based system that can be used for the assessment of preschooler speech and language abilities in Greek [24].

Amongst advanced technologies are expert systems, a category of software based on the theory and methods of artificial intelligence. Expert systems use “knowledge, facts and reasoning techniques to solve problems and make decisions” [25]. Additionally, the knowledge “is of specialist subject and the response of the program can also be an advice instead of a solution” [26]. Expert systems can be useful tools for representing knowledge in a computer based diagnostic system so that they have a significant role in evaluation and diagnosis.

1.3. Aim of the study

The current study reports on the development of an Internet based Speech Pathology Expert System, named APLO (“Oral Language Assessment” (in Greek: Aksiologisi Proforikou Logou – APLO), [29]). APLO is intended to be used in assessment and diagnostic phases of oral speech and language abilities of children four to seven years old. The application is an online system that embeds the expert’s knowledge on oral language assessment. It is designed to provide easy and direct access to Speech and Language Pathologists (SLP) and allow, when necessary, the efficient use by other non-experts in the clinical and professional setting to be involved in oral language learning and strengthening.

2. The development of APLO

Expert systems are normally developed differently than conventional systems as they have no algorithmic solution and they rely on inferences in order to provide a reliable solution [27].

The expert system’s development embodies the development of an integrated system for collecting and processing data. The process of creating an expert system is called knowledge engineering. The development methodology of this expert system is based on the waterfall model (Fig. 1.).

The main stages that characterize the methodology are presented below in subsections 2.1 - 2.7 describing the APLO requirements analysis, analysis, knowledge acquisition, system design, implementation, testing and the online expert system.

2.1. APLO Requirements Analysis

At this initial stage a determination is made of what the system is expected to offer, not how it is presented. The expert system specifications are as follows:

- The approach is mainly user driven.
- The System APLO is an application that uses technology to solve the problem: "evaluation of preschoolers' spoken language".
- The system addresses mainly in the SLP.
- The system also addresses other evaluators, such as psychologists, special education teachers, pediatricians,

developmental teachers, teachers and even parents.

- The system operation is to collect from the evaluator all the necessary information about the child's verbal skills and aspects of speech, through a detailed list of questions and answers.
- Following the completion of the user inputs the system provides fast automated and reliable results with respect to the evaluation of preschoolers spoken language abilities.
- The user should be able to amend, save, retrieve data on a case, and produce automatic diagnostic results.
- The user should be able to work online.

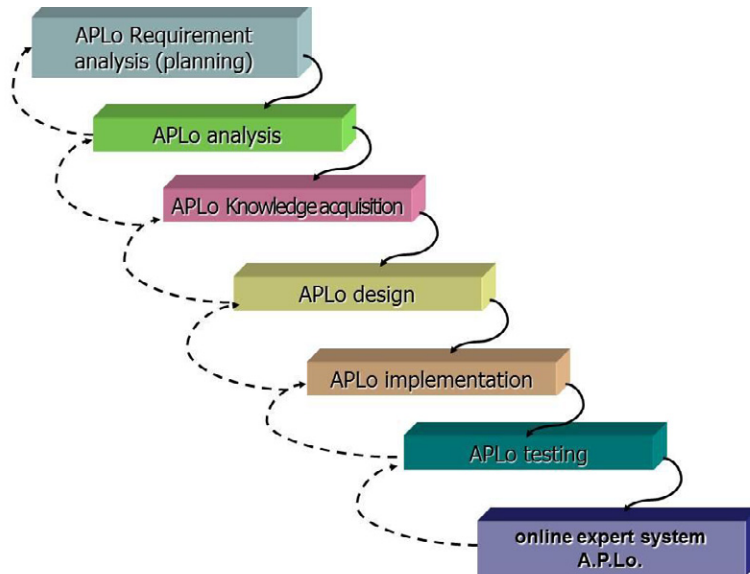


Fig. 1. The APLo development model (waterfall model)

2.2. APLo Analysis

At this stage the desired form of the solution is determined with the following major issues: (a) whether the expert system is a suitable solution for the problem (b) whether there are any ready-made solutions to the problem (c) what the benefits are from the expert system development. Specifically:

- The suitability of an expert system to solve the problem of evaluation is identified [28].
- There are no other reported studies solving the problem of the computer based evaluation of preschoolers' spoken language in accordance to the literature review [24].
- Amongst the offering benefits of developing an online expert system is the ability to provide objective assessment as knowledge is always available. The use of the APLo system for assessment can be done anywhere and anytime as long as there is internet access. Additionally, the system assessment is subjectively and emotionally free [28].

2.3. APLo Knowledge Acquisition

Capturing knowledge (or knowledge acquisition or knowledge extraction) is the most important step in creating the APLo expert system, as the system is intended to make the assessment as an expert. The knowledge acquisition is a painful and time consuming process and the whole success of the system depends on it. It is referred to as the "knowledge acquisition bottleneck" because it limits the development of the expert

system, such as the neck of the bottle prevents the free flow of liquid [27]. For the knowledge acquisition, the relevant literature [2, 6, 29-33] is used in combination with SLPs to confirm the process. Knowledge acquisition could have been done by observing the SLP in diagnostic processes. But in order to avoid validation issues in the evaluation phase of the expert system, three (3) SLP experts provided a safety net, by verifying the knowledge acquired from the literature through informal interviews. Next, the knowledge on speech and language assessment decisions is analyzed and the APLo knowledge model is established. The knowledge model is an intermediate representation with a semi structured format that then can be easily encoded according to the final form of the knowledge representation.

2.4 APLo System Design

Refers to the determination of (a) the form of knowledge representation, (b) the reasoning used to reach conclusions, and (c) the tool for developing the expert system. The system architecture is produced taking into consideration the obligations of (a) the user requirements, (b) the knowledge model, and (c) the technology used. Once the cognitive mechanisms used in the evaluation of preschoolers' spoken language were understood by the analyst, then a suitable form for reproducing these human expert cognitive activities within the software should be designed. The APLo expert system design is shown in Fig. 2 [23]. The design of the online expert system APLo is based on a Multi-Input Multi-Output (MIMO) system that is constructed from smaller subsystems, including the conditions for articulation disorders, phonological disorders, fluency disorders, language disorders, the age milestones, the autism spectrum and mental retardation [23]. Fig. 2 demonstrates how the various subsystems function. The approach on the knowledge representation is a hybrid approach that integrates symbolic rules with neural networks. The symbolic rules are a set of if then rules representing the SLP knowledge. Neural networks are used to provide indicators on the standard deviation on the presence of the disorder (ratings: mild, medium and severe). Specifically, according to the child's age and mother language:

- The articulation disorders subsystem is responsible for applying the set of rules to the user data in order to determine whether a child has an articulation disorder or limitation, involving problems on making sounds.
- The phonological disorders subsystem deals with the application of the set of rules to the user data in order to determine whether a child has an atypical organization of the phonological system involving patterns of sound errors.
- The fluency subsystem includes the set of rules for identifying speech rate and speech disfluencies (the disruptions in the production of speech sounds).
- The language disorders subsystem is responsible for applying the set of rules to the data in order to determine a child at risk of learning disabilities and/or in particular of specific developmental dyslexia. The APLo expert system has been set to find out, according to rules, whether a child is at risk of learning disabilities or some other difficulties. In the APLo expert system set of rules for a child at risk of learning disabilities, the emphasis according to age is given to: motor development (hyperactivity combined with distraction, dysmobility, lack of coordination and perseverance to bring about rapid fatigue, difficulties in fine motor), visual and auditory perception and discrimination, production and comprehension of concepts, difficult to distinguish the container from the content (unable to discern the shape of objects from the box), left - right discrimination, difficulty to understand or remember what they hear in temporal sequence or continuity and difficulties of expression and formulation through a spoken word. The set of rules for a child at risk of dyslexia focuses according to age on: abilities and skills of the child to understand concepts such as body shape, direction, and logic-mathematical concepts (up-down, right-left, forward-backwards), prewriting skills, visual and sound discrimination, articulation/phonology, laterality, motor development and memory.
- The age milestones subsystem deals with the set of rules responsible for applying conditions to the data in order to determine whether a child is performing according to the average age speech and motor

expectations.

- The autism spectrum subsystem presents the set of rules in order to determine whether a child is in the autism spectrum disorders with emphasis on the severity of the speech and language eliminations.
- The mental retardation subsystem encodes the set of rules in order to determine the speech and language eliminations of a child with mental retardation.

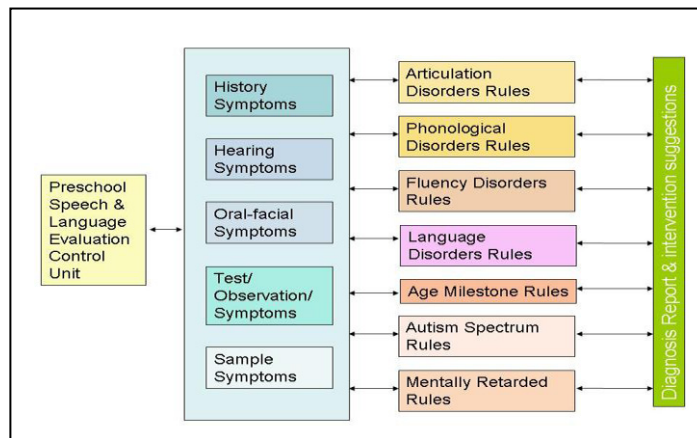


Fig. 2. The Design of APLo expert system for assessing preschool speech and language disorders [23]

When the subsystems complete the application rules, then the results are included on the diagnostic report along with possible intervention directions.

2.5. APLo implementation

At the implementation stage, the coding is based on the design of the knowledge model. The application and the user interface has been implemented in PHP v5.3, an open source programming language used for web programming, that meets the needs of the application. APLo development has been implemented in such a way that the evaluation mechanism (the rules in inference engine, responsible for the evaluation) can be edited (added, modified, extended, deleted) without the need of interfering with the application code. This is accomplished by storing the rules (in forms of logical expressions) in a database application, not in the application code. MySQL is a relational database management system (RDBMS) that does not provide a Graphics User Interface (GUI). Therefore, a free graphical management environment, SQLyog Community Edition v8.x (<http://code.google.com/p/sqllyog/>), is used to handle database tables and data processing for MySQL (MySQL GUI), and also Microsoft Access data base for processes.

2.6. APLo Testing

The testing stage involves the following procedures: (a) verification (in collaboration with end users), (b) debugging (the code), and (c) validation (using real cases) [28].

2.7. Online Expert system APLo

The final version 1.0 of the expert APLO system has been accomplished.

3. Using the APLO system

The proposed system is a web based speech and language pathology expert system that evaluates kindergarten children's oral language. APLO is an Internet based Speech Pathology Diagnostic Expert System that constitutes a computerized approach for the evaluation of preschoolers' communication skills.

When entering the system the user has the option to start a new evaluation, retrieve the results of a previous evaluation, amend data on a previous evaluation and get information about APLO (Fig. 3). The user firstly has to specify his/her profession (SLP, teacher, special education teacher, pediatrician, developmental pediatrician, psychologist/psychiatrist, parent, other). Then the system gathers data on the child's speech and language symptoms from the user who answers questions on the matter. Data is gathered in the following sections: demographics and medical/communication history (10 questions), verbal communication (42 questions), non-verbal communication (30 questions), orofacial examination (10 questions), articulation/phonology (29 questions), structure of language (29 questions), psychomotor development (26 questions), sound discrimination (8 questions), and memory (8 questions) (Fig. 4). The expert system, with a range of subsystems i.e. articulation subsystem, phonological subsystem, language disorders subsystem, etc., applies various sets of "if-then" rules to the data in order to produce articulation results, phonological results, language disorders results, and so on. When the evaluation processes is completed by all the subsystems, the results are shown in the diagnostic report which also includes possible guidelines for intervention [28].

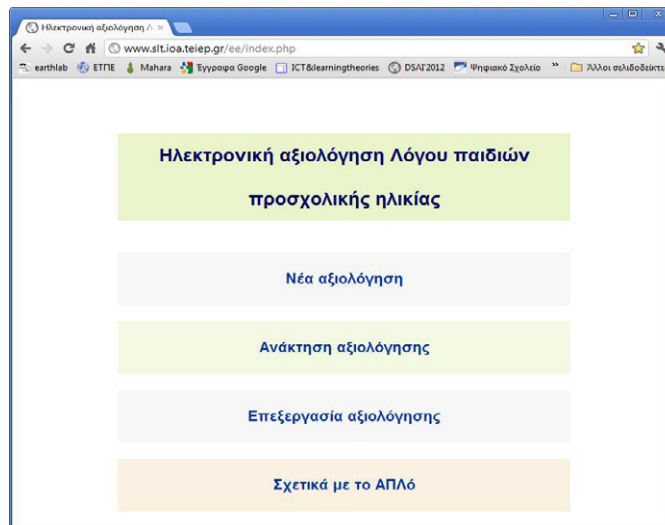


Fig. 3. The main menu of APLO Expert system

Fig. 4. APLO menu for inserting evaluation data on demographics

4. Conclusion

ICT can offer valuable clinical and educational tools. Artificial intelligence via the development of expert systems can create the circumstances to integrate diagnostic decisions of an experienced SLP. The representation of how an experienced SLP comes to conclusions on the evaluation process is implemented in APLO. This approach is a hybrid one that integrates the specified rules and adopted symbolic rules with neural networks providing indicators of disorder classification. There are no other relevant systems yet to be used for diagnostic assessment procedures of 4 to 7 years old children's oral speech and language in Greek.

Subsequently to the APLO system design, the accomplished online expert system can be easily update and modified with no need of changing the actual code. The rules of the system can be modified directly on the relevant database according to scientific developments.

The innovation of APLO system is that it is a multi-input multi-output system that integrates a systemic approach for assessing children's speech and language abilities. Furthermore, clinicians and educators can interact online in order to accomplish diagnostic results.

Concluding, an online speech and language pathology system was developed with the aim to provide the SLP and other professionals with an additional tool on the diagnosis of disorders and difficulties in preschoolers' oral speech. The tool embodies the user ability to answer certain questions and then it gives an automatic evaluating response and subsequently generates a list of weaknesses or disorders located. This feedback can be used by the SPL and other professionals to plan therapy or learning tasks and support speech and language issues. Future work may extend in many tasks including computer-based tools and investigation of the use in the clinical and the educational setting.

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